Usage areas, biological activities and volatile oil compounds of *Matricaria aurea* and *Matricaria chamomilla*

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Plants are natural products responsible for many biological activities. It is quite common to use plants that attract attention with their nutritive properties within the scope of complementary medicine. *Matricaria* species, which have naturally distributed, are among the plants used in traditional medicine. Revealing the biological activities of plants is very important in terms of their potential use. In this study, the usage areas, chemical contents and biological activities of *Matricaria* species reported in the literature were compiled. According to the findings, it was seen that it was used for health and cosmetic purposes. In addition, it has been observed that *Matricaria* species have biological activities such as antioxidant, antimicrobial and anticancer. It was observed that the dominant compounds from different *Matricaria* species were 1,5-Bis (dicyclohexylphosphino)-pentane (3.95-44.7%) and α-bisabolol (2.2-56.86%). According to the literature data, *Matricaria* species are an important natural resource. As a result, it is predicted that *Matricaria* species may be an important source in pharmacological studies.

Keywords: antioxidant; antimicrobial; chamomile; *Matricaria*; traditional medicine

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1. INTRODUCTION

Plants are highly significant materials that are utilized by humans for various purposes, either by obtaining them from their natural habitats or through cultivation (Mohammed et al., 2022). Plants are considered a fundamental component of human dietary lists due to their ability to contain vitamins, minerals, and essential nutrients within their structures (Dastagir et al., 2022; Sevindik et al., 2017). Throughout history, humans have utilized plants for a multitude of purposes, including but not limited to shelter, warmth, equipment, sustenance, and medicinal applications. Plants constitute the basis for combating diseases in both developing and underdeveloped countries worldwide (Dayangaç et al., 2021; Mohammed, Günal, Şabik, Akgül and Sevindik, 2020). In this context, it is highly important to evaluate not only the nutritional properties of plants but also their potential from a medicinal perspective (Khan et al., 2023; Mohammed, Günal, Pehlivan, Doğan, Sevindik and Akgül, 2020). Numerous studies have reported that plants possess a variety of activities such as antioxidant, anti-inflammatory, anticancer, antimicrobial, antiproliferative, hepatoprotective, and DNA-protective (Abbas et al., 2022; Benkhnigue et al., 2023; Mazher et al., 2023; Mohammed et al., 2018; 2019; Unal et al., 2022; Uysal et al., 2023). In this study, the reported usage areas, chemical contents, and biological activities of *Matricaria* species in the literature have been compiled.

1.1. *Matricaria* species and their usage areas

Matricaria, a member of the Asteraceae family, is one of the more important medicinal plant species native to Southern and Eastern Europe. In addition to these regions, Germany, Hungary, France, Egypt, Russia and Brazil are also areas where it is cultivated. It is known that the first emergence of it in history was during the Babur period in India. Plants belonging to the *Matricaria* species are annual plants with thin needle-shaped roots that penetrate the soil in a straight manner. The stem of the plant is characterized by its branching structure, with a high degree of branching observed. It is capable of attaining heights ranging from 10 to 80 centimeters, and its leaves are long and narrow. It is also known that the number of petals in a flower is two or three. The flower heads have been arranged separately, with a diameter range from 10 to 30 millimeters. The flower heads have a stem, and are heterogeneous in nature. The flowers of this species consist of five-toothed, golden-yellow tubules measuring 1.5-2.5 mm in length, which are always terminated by a glandular tube. The petals on 11-27 white flowers are arranged concentrically and measure 6-11 mm in length and 3.5 mm in width. The fruit has a yellowish-brown rind (Franz et al., 2005; Handa et al., 1957; Ivens, 1979; Svab, 1979). The literature documents the various methods and techniques employed for different purposes in the utilization of *Matricaria* species. Upon examination of the traditional application of the *Matricaria* genus, it is observed that various parts of the plant, including the flower, leaf, stem, and whole plant, are utilized. The utilization of various techniques such as infusion, boiling, steam inhalation, bathing, and compress have been preferred among plants application methods. It has been observed that there are various health applications for conditions such as diabetes, nerve disorders, diarrhea, angina, thrush, abscess, painful menstrual periods, gastralgia, digestive disorders, female genital infections, kidney stones, sedation, antiseptic, nausea, gastrointestinal disorders, eye irritation, sciatic pain, oral, throat, ear, and skin infections, spasm conditions, colds, sprains, fractures, liver disorders, skin and mucous membrane inflammation, burn treatment, and cough. In addition, it has applications in facial cleansing, tea consumption, oral hygiene, and shampoo fragrance (Di Novella et al., 2013; Eddouks et al., 2017; Idm'hand et al., 2020; Kozuharova, 2013; Marković et al., 2021; Mikou et al., 2015; Mrabti et al., 2019; Naceiri Mrabti et al., 2021; Parada et al., 2009; Pieroni, 2017; Tuttolomondo et al., 2014).

2. BIOLOGICAL ACTIVITIES

Plants are natural resources responsible for many biological activities (Mohammed et al., 2021). In this study, the biological activity studies of *Matricaria* species reported in the literature were compiled and shown in Table 1.

2.1. Antioxidant activity

Free radicals are oxidant compounds that are produced as a result of metabolic activities (Krupodorova and Sevindik, 2020). Elevated levels of oxidizing compounds can be highly detrimental to living organisms. The antioxidant defense system plays a role in preventing or suppressing these harmful effects (Bal et al., 2017). In cases where the antioxidant defense system is insufficient, oxidative stress occurs (Eraslan et al., 2021). Serious illnesses such as cancer, cardiovascular diseases, multiple sclerosis, neurodegenerative diseases, Alzheimer's, and Parkinson's may manifest in individuals as a result of oxidative stress (Bal et al., 2023; Saridogan et al., 2021; Selamoglu et al., 2020). Supplemental antioxidants play a crucial role in reducing the potential effects of oxidative stress (Akgül et al., 2022). Within this scope, a compilation of studies on the antioxidant activity of *Matricaria* species reported in the literature, has been presented (Table 1). The volatile oils of the leaves, stems, flowers, and roots of *Matricaria aurea* collected from Tunisia were reported to exhibit antioxidant activities as determined by ABTS and DPPH tests (Kheder et al., 2014). They compared the obtained results with the synthetic antioxidant Trolox value. The results of the study indicate that the DPPH assay exhibited a range of inhibition values between 1.06% and 24.53%. Furthermore, it has been reported that the ABTS assay exhibits ion neutralization values ranging from 0.1% to 21.2% (Kheder et al., 2014). According to a study conducted in Iran, it has been reported that the ethyl acetate and methanol solvents of *M. aurea* exhibit high antioxidant activity as determined by the DPPH radical scavenging assay and phosphomolybdenum reduction assay (Yousefbeyk et al., 2022). It has been reported that the water and other solvents of the flowers of *M. aurea* collected from Jordan exhibit inhibitory effects on linoleic acid peroxidation, with inhibition percentages of 91.2% and 77%, respectively. Furthermore, it has been reported that the DPPH values of water and other solvents were 92.8% and 90.3%, respectively. Additionally, the obtained results were evaluated in liposome model systems (Mohammad Al-Ismail and Aburjai, 2004). It has been reported that the IC_{50} values of the methanol and ethanol solvents of *M. aurea* collected from Jordan were 51.5 and 19.8 μg/mL, respectively, while the FRAP test results were 954.33 and 814.83 μM/mg, respectively (Tarawneh et al., 2008). It has been reported that the EC_{50} value of the volatile oil of *M. chamomilla* collected from Bosnia and Herzegovina on the DPPH test was 2.07 mg/mL after a 90-minute incubation period (Stanojevic et al., 2016). The LC_{50} values, known as the potency, of the essential oil and methanol extract of *M. chamomilla* collected from Djibouti were reported to be 4.18 and 1.83 μg/mL, respectively. It was also reported that the inhibition potential of β-carotene-linoleic acid system was 12.69% and 11.37%, respectively. To compare the results, butylated hydroxytoluene (BHT) was used as a positive control (Abdoul-Latif et al., 2011). In a study conducted in South Korea, it was reported that ethanol extract was more effective than aqueous extract in the antioxidant protection factor of *M. chamomilla* (Cho et al., 2005). DPPH test result of essential oil obtained from *M. chamomilla* sample was 533.89 μg/mL, the iron ion chelating ability was 943.61 μg/mL, and the β-carotene bleaching test result was 31.01%. It was also reported that the DPPH test result of the honey obtained from the *M. chamomilla* sample was 1945.38 μg/mL, the iron ion chelating ability was 1773.78 μg/mL, and the β-carotene bleaching test result was 745.54%. Butylated hydroxytoluene (BHT) was used as a positive control to compare the results. The BHT value was reported to be 14.24 $\pm$ 1.32 μg/mL (Qasem et al., 2022). It has been reported that the volatile oil of *M. chamomilla* collected from Egypt exhibits a DPPH activity of 91.7% at a concentration of 400 μg/mL. Butylated hydroxytoluene (BHT) was used as a positive control to compare the results. The BHT value was reported to be 75.6% at a concentration of 400 μg/mL (Ali, 2013). According to the literature, it has been observed that *Matricaria* species have antioxidant potential.

2.2. Antimicrobial activity

In recent years, the increase in the number of diseases caused by microorganisms draws attention (Baba et al., 2020). The general reason for this is thought to be the increase in the number of resistant microorganisms due to unconscious drug use. In recent years, researchers have turned to the discovery of new antimicrobial drugs (Mohammed et al., 2023). Due to the possible side effects of synthetic drugs, people have started to prefer the use of natural antimicrobial drugs. In this context, plants are a very important resource for the discovery of new antimicrobial drugs (Bal et al., 2017; Islek et al., 2021). It has been reported that the MIC values of the essential oil of different parts of *M. aurea* collected from Tunisia against *Vibrio harveyi, Vibrio vulnificus, Pseudomonas aeruginosa, Vibrio alginolyticus, Vibrio fluvialis, Micrococcus luteus, Escherichia coli, Staphylococcus aureus, Salmonella wien, Bacilus cocus, Vibrio parahaemolyticus, Candida albicans, Candida tropicalis, Candida parapsilolis* and *Candida glabrata* vary about 50->1000 μg/mL of the leaves, 20->1000 μg/mL of flowers, 10->1000 μg/mL of

Table 1. Biological activity of *Matricaria aurea* and *Matricaria chamomilla*.

Plant species	Biological activities	Extracts	Localities	References
Matricaria aurea (Loefl.) Sch.Bip.	Antioxidant, antimicrobial, analgesic, anti-inflammatory	Ethanol, ethyl acetate, methanol, chloroform, acetone, water	Saudi Arabia, Tunisia, Jordan, Iranian	(Kheder et al., 2014; Khodadadi et al., 2011; Mohammad Al-Ismail and Aburjai, 2004; Qnais, 2011; Rizwana et al., 2016; Tarawneh et al., 2008; Yousefbeyk et al., 2022)
Matricaria chamomilla L.	Antioxidant, antimicrobial, angiotensin, antiaflatoxigenic, anticancer, anti-inflammatory, antidiabetic,	methanol, water, ethanol	Bosnia and Herzegovina, Pakistan, Djibouti, South Korea, Morocco, Egypt	(Abdoul-Latif et al., 2011; Ali, 2013; Cho et al., 2005; Mehmood et al., 2015; Qasem et al., 2022; Stanojevic et al., 2016)

roots parts and 35->1000 µg/mL of the stems (Kheder et al., 2014). It has been reported that chloroform, ethyl acetate, acetone, ethanol and methanol extract of the flowers parts of *M. aurea* collected from Saudi Arabia are effective between 0.2-100 mg/mL against *Staphylococus aureus, Bacillus subtilis, Streptococcus pyogenes, Enterococcus faecalis, Escherichia coli, Klebsiella pneumonia, Alternaria alternata, Aspergillus niger, Aspergillus flavus, Fusarium oxysporum, Fusarium solani* and *Colletotrichum gleosporoides* (Rizwana et al., 2016). In a study conducted in Iran, it was reported that ethyl acetate and methanol extract of *M. aurea* showed high activity against *Bacillus subtilis* (MIC 1.56 and 12.5 mg/mL) and *Staphylococcus aureus* (MIC 0.78 and 12.5 mg/mL) (Yousefbeyk et al., 2022). It has been reported that the essential oil of *M. chamomilla* collected from Bosnia and Herzegovina has a 13.3-40 mm zone of inhibition against *Listeria monocytogenes, Escherichia coli, Salmonella enterica* and *Staphylococcus aureus* (Stanojevic et al., 2016). It has been reported that the MIC values of the essential oil and methanol extract of *M. chamomilla* collected from Djibouti against *Bacillus cereus, Enterococcus faecalis, Escherichia coli, Listeria innocua, Salmonella enterica, Shigella dysenteria, Staphylococcus aureus, Staphylococcus camorum, Proteus mirabilis, Pseudomonas aeruginosa, Streptococcus pyogenes, Candida albicans, Aspergillus niger* and *Aspergillus* sp. are between 1-16 µg/mL of the essential oil and 25-200 µg/mL of the methanol extract (Abdoul-Latif et al., 2011). In a study conducted in South Korea, it was reported that water extract of *M. chamomilla* leaves did not have antimicrobial activity against *Helicobacter pylori*, but ethanol extract revealed mild antimicrobial activity as a 9.42 mm clean zone (Cho et al., 2005). It has been reported that the essential oil of *M. chamomilla* collected from Morocco has an inhibition zone of 11.20-22.97 mm, and honey obtained from the *M. chamomilla* sample of 8.10-13.90 mm against *Escherichia coli, Proteus mirabilis, Salmonella enterica Typhimurium, Pseudomonas aeruginosa, Staphylococcus aureus, Listeria monocytogenes, Candida albicans, Trichophyton rubrum* and *Aspergillus niger* (Qasem et al., 2022). It has been reported that ethanol and methanol extract of *M. aurea* collected from Jordan do not show any effect against *Candida albicans, Aspergillus niger, Penicillium chrysogenum, Aspergillus nidulans* (Tarawneh et al., 2008). In this context, according to literature data, it has been observed that *Matricaria* species have important antimicrobial potentials.

2.3. Other activities

In a study conducted in South Korea, it was reported that the angiotensin converting enzyme inhibitory effect of *M. chamomilla* was 57.98% in water extract and 91.36% in ethanol extract (Cho et al., 2005). It has been reported that the essential oil of *M. chamomilla* collected from Egypt has a cell growth inhibition of 7-89% against the MCF-7 cell line. In addition, in the same study, it was reported that the essential oil of *M. chamomilla* completely inhibited aflatoxin B1 (AFB1) production at 800 ppm (Ali, 2013). The anti-diabetic effect of the essential oil of *M. chamomilla* collected from Morocco has been reported as α-glucosidase IC_{50} value of 265.57 µg/mL and α-amylase IC_{50} value as 121.44 µg/mL (Qasem et al., 2022). In addition, α-glucosidase IC_{50} value of honey obtained from the *M. chamomilla* sample has been reported as 1351.02 µg/mL and α-amylase IC_{50} value as 981.44 µg/mL. In the same study, it was reported that the anti-inflammatory effect was 64% in essential oil and 76% in honey at 100 mg/kg after 6 hours (Qasem et al., 2022). It has been reported that the ethanol extract of *M. aurea* collected from Jordan has analgesic effects in rats, using the cold water tail flick test and using tail dip, tail clip, acetic acid-induced writhing and formalin pain tests (Qnais, 2011). The anti-inflammatory result of the LC_{50} values, expressed as the effect potential, of the hydro-alcoholic extract of *M. aurea* collected from Iran was reported to be 1305 µg/mL (Khodadadi et al., 2011). It has been reported that *M. chamomilla* collected from Pakistan has antidiarrheal, antisecretory and antispasmodic activities mainly mediated by weak Ca^{++} and K^{+} -channels activation (Mehmood et al., 2015).

3. CHEMICAL CONTENTS

Plants synthesize many biologically active compounds in their bodies. These compounds are responsible for many different pharmacological activities (Akgül et al., 2022; Selamoglu et al., 2017). In this study, the chemical compounds of *Matricaria* species reported in the literature were compiled. The obtained results are shown in Table 2.

It has been reported that the main components in the essential oil content of *M. aurea* species are pinane (0.03-1.25%), octahydrocoumarin 5,75,7-dimethyl (0.05-19.16%), caryophyllene oxide (0.06-1.54%), β-Farnesol (0.17-2.04%), α-Bisabolol oxide (1.16-4.64%), 2,5-Bis1 ,1-8 dimethylethyl-thiophene (0.02-10.95), 1,5-Bis (dicyclohexylphosphino)-pentane (3.95-44.7%), 2-Ethoxy-6-ethyl-4,4,5-trimetethyl 1,3-dioxa -4-sila-2-boracyclohex-5-ene (6.49-37.99%) and n-eicosane (0.42-6.59%) (Kheder et al., 2014). The main components in the essential oil content of *M. chamomilla* species are limonene (0.99-1.22%), (E)-β-farnesene (1.62-53.45%), bisabolol oxide B (1.2-35.63%), azulene-7ethyl-1,4 dimethyl (4.1-19.27%), bisabolol oxide A (2.19-47.7%), 8-Isobutyryloxy isobornyl isobutyrate (11.15-14.03%), α-bisabolol (2.2-56.86%), trans-trans-farnesol (15.64%), cis-β-farnesine (7.12) %), α-cubebene (2.69%), germacene D (2.5-6.2%), bicyclogermacrene (1.7%), cis-z- α-bisabolene expoxide (9.8%), cis -ene-yne-dicycloether (4%), trans-ene-yne-dicycloether (3.3%), α-farnesene (8.3-9.3%), spiroether (5.6 %), cis-bicycloether (5.0%) and spathulenol (0.81%) (Ali, 2013; Ayoughi et al., 2011; Göger et al., 2018; Pirzad et al., 2006; Rahmati et al., 2011; Rathore and Kumar, 2021; Satyal et al., 2015; Stanojevic et al., 2016; Tolouee et al., 2010; Tsivelika et al., 2018). 1.5-Bis (dicyclohexylphosphino)-

Table 2. Volatile oil compounds (%) of *Matricaria aurea* and *Matricaria chamomilla*.

Plant species	Geographic regions	Used Parts	Chemical contents	References
Matricaria aurea(Loefl.) Sch.Bip.	Tunisia	Aerial, stem	Pinene (0.03%-1.25%), octahydrocoumarin 5,75,7-dimethyl (0.05%-19.16%), caryophyllene oxide (0.06%-1.54%), β-Farnesol (0.17%-2.04%), α-Bisabolol oxide (1.16%-4.64%), 2,5-Bis1,1-8 dimethyleth) thiophene (0.02%-10.95), 1,5-Bis (dicyclohexylphosphino)-pentane (3.95%-44.7%), 2-Ethoxy-6-ethyl-4,4,5- trimetethyl 1,3-dioxa-4-sila-2-boracyclohex-5-ene (6.49%-37.99%), n-eicosane (0.42%-6.59%)	(Kheder et al., 2014)
Matricaria chamomilla L.	Iranian, Egypt, Turkey, Bosnia and Herzegovina, Serbia, India, Greece, Nepal,	Aerial parts	limonene (0.99%-1.22%), (E)-β-farnesene (1.62%-53.45%), bisabolol oxide B (1.2%-35.63%), azulene-7ethyl-1,4 dimethyl (4.1%-19.27%), bisabolol oxide A (2.19%-47.7%), 8-Isobutyryloxy isobornyl isobutyrate (11.15%-14.03%), trans-trans-farnesol (15.64%), cis-β-farnesene (7.12%), α-cubebene (2.69%), germacene D (2.5%-6.2%), bicyclogermacrene (1.7%), α-bisabolol (2.2%-56.86%), cis-z-α-bisabolene epoxide (9.8%), cis-ene-yne-dicycloether (4%), trans-ene-yne-dicycloether (3.3%), α-farnesene (8.3%-9.3 %), spiroether (5.6 %), cis-bicycloether (5.0%), spathulenol (0.81%)	(Ali, 2013; Ayoughi et al., 2011; Göger et al., 2018; Pirzad et al., 2006; Rahmati et al., 2011; Rathore and Kumar, 2021; Satyal et al., 2015; Stanojevic et al., 2016; Tolouee et al., 2010; Tsivelika et al., 2018)

pentane (3.95-44.7%) was found to be the highest compound detected in *M. aurea*, while α-bisabolol (2.2-56.86%), was the highest detected compound in *M. chamomilla*. In this context, it is thought that the value range of the compounds determined according to literature data will be a reference source for future studies. In addition, it is thought that the presence of all the identified compounds together will help speed up the studies and provide information about the major compounds.

4. CONCLUSION

In this study, the usage areas, chemical contents and biological activities of *Matricaria* species were compiled according to the literature data. According to the findings, these plant species are widely used for health and cosmetic purposes. It has also been reported as a very important source of antioxidant and antimicrobial activity. In addition, it was observed that the dominant compound among *Matricaria* species was 1,5-bis(dicyclohexylphosphino)–pentane (3.95-44.7%) and α-bisabolol (2.2–56.86%), It has been determined that it can be an important natural source for the mentioned compounds.

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